DEVELOPMENT TRENDS AND PROSPECTS FOR eVTOL: A NEW MODE OF AIR MOBILITY

Hideki Kinjo
Industry Innovation Dept., Technology & Innovation Studies Div.
Mitsui & Co. Global Strategic Studies Institute

SUMMARY

- Development activities are gaining momentum for “electric vertical takeoff and landing aircraft” (eVTOL), which is designed to transport several passengers over short distances by air.
- Technology advancements, such as batteries and motors in the automotive industry and autopilot navigation in the drone industry are the backgrounds.
- Many startups, as well as major aircraft manufacturers, are now entering into eVTOL aircraft development.
- Among the services envisioned, the US company Uber aims to launch an air taxi service in the first half of the 2020s.
- Challenges with respect to aircraft development have mainly to do with batteries, while on the services front, ensuring safety and securing profitability are the issues.
- As for eVTOL initial spread in the market, it may possibly be for first aid and other emergency response services and in emerging economies where flight regulations are less stringent.

The development of electric vertical takeoff and landing aircraft (eVTOL) is gaining momentum. Three-dimensional mobility in the sky is expected to provide passengers with much shorter travel times and greater convenience. This report discusses the unique features of eVTOL, trends in aircraft development, moves in the area of services, challenges to make eVTOL travel a reality, and future prospects.

eVTOL REPRESENTS A NEW MODE OF MOBILITY MADE POSSIBLE BY TRANSFERRING TECHNOLOGIES FROM OTHER INDUSTRIES

The eVTOL can be described as a vehicle that fits somewhere in between a drone and a conventional airplane. The eVTOL features vertical takeoff and landing (VTOL) capability, electrification of lift and thrust (rotating a propeller/rotor with a motor), and automation of controls (Fig. 1). Envisioned applications for passenger transportation include usage as air taxis, for emergency response (first-aid, police, rescue), and for leisure activities. As for the transportation of goods, eVTOL would offer larger capacity for freight transport than ordinary drones. Fueling the growing momentum behind development are advancements in battery and motor technologies along with related control technologies, led by the automotive industry, and autopilot technologies cultivated in the drone industry, as well as technology advancements for reducing aircraft weight with carbon fiber composite materials.

Figure 1: Unique Features of eVTOL

- ✓ Vertical takeoff and landing capability
- ✓ Electrification of lift and thrust
- ✓ Automation of controls

Source: Compiled by MGSSI

One type of aircraft that has the same vertical takeoff and landing capabilities is helicopters. A comparison with the eVTOL is shown in Fig. 2. The eVTOL has a flight range of approximately several tens of kilometers to 300 km, which is shorter than approximately 600 to 800 km for helicopters. Also, eVTOL has a smaller capacity for passengers. However, the advantages of eVTOL in comparison to helicopters include: (1) low noise level, (2) low operating costs, and (3) a high degree of safety.

Figure 2: Comparison of Helicopter versus eVTOL

	Helicopter	eVTOL Aircraft
Aircraft schematic	Main rotor  Tail rotor*	Rotors 
Rotor	• One main rotor • With tail rotor	• Multiple small rotors • Without tail rotor**
Source of power to drive the rotor(s)	Engine	Motor
Power source	Fuel	• Batteries only • Combination of batteries and gas turbine generator
Cruising range***	Approximately 600 – 800 km	Approximately several tens of km – 300 km
Passenger capacity***	Approximately several –15 (maximum)	Approximately 5 (maximum)
Size of takeoff and landing area	Larger than the full length and full width of the landing aircraft (in the case of ground level sites)	—

Notes:
*As the aircraft itself attempts to rotate in the opposite direction of the motion of the main rotor, the tail rotor produces a force to cancel the torque.
** Because the eVTOL is equipped with rotors that turn clockwise as well as rotors that turn counter-clockwise, the force of the aircraft itself attempting to rotate is cancelled.
*** Because of differences among models, figures are for reference only.
Source: Compiled by MGSSI

With respect to (1), the noise level of eVTOL is expected to be approximately one-fourth that of existing helicopters due to the electrification of the aircraft's lift and thrust. Noise is an important factor for public acceptance of eVTOL as air mobility. Low noise would make it more feasible for flying in densely populated areas and at low altitudes.

Regarding (2), electrification eliminates a complicated rotation mechanism and fuel system, and is thereby expected to simplify the aircraft structure and reduce maintenance costs. The maintenance cost of a helicopter is said to be approximately 60% of its operation cost, but it is assumed that the maintenance cost of an eVTOL can be reduced to approximately 20% of the operation cost (estimated by the US company Uber Technologies[1]).

In terms of (3), in addition to fewer failures anticipated due to the simplification of the aircraft structure, enhanced safety is also expected due to an automation of the controls (or assistance to pilots). Helicopters are said to be difficult to maneuver and easily cause human errors. In addition, helicopters have only one rotor that generates lift and thrust, and if it fails, flight becomes difficult. In comparison, the eVTOL is more robust as it is equipped with multiple rotors; even if one or more of them are damaged, the others can cover the resulting inoperability.

Because of factors (1) – (3), eVTOL can be a means of transportation with new value that helicopters do not provide. While VTOL prices vary depending on their model, among two-seaters, the Robinson R22 helicopter (cruising range: approximately 460 km), manufactured by well-established US company Robinson Helicopter, is expected to be priced at approximately US$300,000, and the eVTOL made by German venture company Volocopter (cruising range: approximately 27 km) at approximately US$340,000.

MORE NEWCOMERS ENTERING THE FIELD OF eVTOL AIRCRAFT DEVELOPMENT

It is said that more than 80 companies, including both startups and major automotive and aircraft manufacturers, have entered the field of eVTOL aircraft development.

Startup companies include Volocopter (Germany), EHang (China), Kitty Hawk (US), Lilium (Germany), Opener (US), Hoversurf (US), Joby Aviation (US), and CARTIVATOR (Japan).

Among the frontrunners is Volocopter. The company's model "Volocopter 2X" has the capacity for two people (one pilot and one passenger), and its shape is similar to a small general-purpose drone called a multicopter. The aircraft has a width of approximately 9 m, and weighs approximately 290 kg as it is made of carbon fiber composite material used for general aircraft. It flies powered by 18 small rotors driven by lithium-ion batteries. The maximum airspeed is approximately 100 km/h, maximum cruising range is approximately 27 km, and 40 minutes' fast battery charging is possible. The noise level is approximately one-seventh that of a helicopter. It is designed to enable stable flight with a single control stick and to cope with partial rotor failure. Key aviation electronics, such as equipment for aircraft position control, are supplied by the US company Honeywell. After a successful manned flight in 2016, test flights were conducted in Dubai, UAE, in 2017. Volocopter plans to conduct a trial flight in the second half of 2019 in Singapore with the support of the Singaporean government, and aims to commercialize the aircraft in the first half of the 2020s. For the pilot project in Singapore, dedicated takeoff and landing areas will be built on an experimental basis, and the user-friendliness of the boarding process, along with other aspects, will be verified. The company is also focusing on market development and has partnered with the German airport management company Fraport in the development of eVTOL air taxi services based at airports. Volocopter has the backing of the German automaker Daimler and others. The aircraft specifications and development trends related to the leading startups are shown in Fig. 3.

[1]"Fast-Forwarding to a Future of On-Demand Urban Air Transportation", Uber, 2016

Figure 3: Aircraft Specifications and Development Trends for Leading Startups

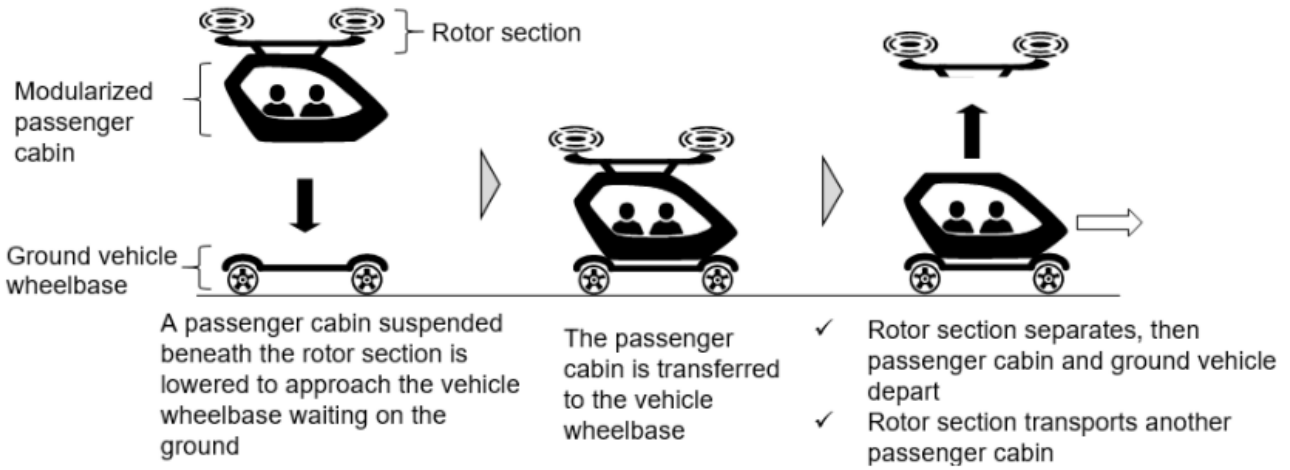
	EHang	Kitty Hawk	Lilium
Head Office	China	US	Germany
Aircraft	EHang 216	Cora	Lilium Jet
Capacity (persons)	2	2	5
Width	Approx. 4 m	Approx. 11 m	Approx.11 m
No. of rotors	16	12	36
Flight speed	Approx. 130 km/h	Approx. 180 km/h	Approx. 300 km/h
Cruising range	Approx. 70 km	Approx. 100 km	Approx. 300 km
Development trend	• Planning to begin mass production in 2021 • Performance record for over 1,000 flights • Collaboration with Austrian aeronautical equipment manufacturer FACC	• Planning to launch air taxi service in New Zealand in the first half of 2020s • Performance record for over 400 flights • Collaboration with Air New Zealand	• Aiming to realize practical use by 2025 • Conducted successful VTOL test flight in April 2019 • Procured approximately $90 million from China's Tencent and others

Source: Compiled by MGSSI
Approx. = Approximately

Major companies that are involved in this field include Airbus (Europe), Boeing (US), and Bell Helicopter Textron (US). In addition to utilizing the strengths of their aircraft manufacturing technologies and existing supply chains, these companies aim to secure their positions in the mobility services market where changes, including the diversification of players, are rapidly unfolding.

Airbus is developing a one-seater called “Vahana” and a four-seater named “City Airbus”. For Vahana, the company succeeded in conducting the first flight of a prototype in 2018, and in February 2019, the report of successful vertical take-off and landing and level flight achieved during a test flight that lasted approximately 7 minutes became open to public. The electronic parts company MAGicALL(US) supplies the motor, one of the crucial components for this aircraft. As for the City Airbus, it has been reported that the first successful flight was realized in May 2019. The company aims to commercialize Vahana and City Airbus by 2020 and 2023, respectively. Airbus has set its sights on not only eVTOL aircraft sales but also on business development throughout the value chain, such as for related services using eVTOL. The company is collaborating with the US company Voom, which has been providing on-demand helicopter taxi services (air taxis) mainly in Brazil's urban areas since 2017, to establish a business base for air traffic systems in urban areas. Voom is expected to launch its service in Shenzhen, China, in 2019, and based on this, Airbus plans to introduce an air taxi using eVTOL in Shenzhen from the mid-2020s. In addition, the company has partnered with the German automaker Audi to study the concept of seamless connecting of air and land mobility from a long-term perspective. The concept, called “Pop.Up Next,” is an innovative idea of modularizing the passenger cabin in the form of a container and transferring it between the aircraft’s hovering rotor section and the wheelbase section on the ground (Fig. 4).

Figure 4: Concept of Pop.Up Next



Source: Compiled by MGSSI based on Airbus company materials

In January 2019, Boeing was in the process of confirming the VTOL capability of a prototype aircraft. The aircraft is being developed by Aurora Flight Sciences (US), which is strong in autopilot technologies and which Boeing acquired in 2017.

Also in January 2019, Bell Helicopter Textron unveiled its large five-seater “Bell Nexus”. And in April 2019, the company announced its business alliance with Sumitomo Corporation.

UBER, A DRIVING FORCE FOR SERVICES USING eVTOL

In the market for services using eVTOL, the focus is now on the introduction of air taxi services in urban areas in both advanced and emerging countries. Existing air taxis that are similar in nature include on-demand helicopter services for which reservations can be made via mobile apps (for example, a service offered by Voom mentioned earlier), but air taxis using eVTOL specialize in travel over a shorter distance. Transportation services using eVTOL in urban areas, in general, are referred to as “Urban Air Mobility” (may include helicopter air taxis in some cases).

What will an air taxi of eVTOL look like? Currently, companies are pushing forward with air taxi projects in the US, Germany, Singapore, and elsewhere. In the US, a project underway in the State of Texas is expected to connect Dallas Fort Worth International Airport, Downtown Dallas, and Frisco, a rapidly developing commuter town of Dallas. It is assumed that users of this air taxi service will be primarily business travelers who use the airport frequently. In Germany, eVTOL-based air taxis will meet the transportation demand from travelers transiting to and from Frankfurt Airport. In Singapore, one of the possible flight routes mentioned would connect a coastal area with the central business area, suggesting that business persons would be service users. Moreover, in the case of Singapore, shoppers at large shopping malls equipped with takeoff and landing areas for eVTOL are also expected to use the service.

On a related note, we should consider what type of person would be interested in using an eVTOL air taxi. Airbus has conducted a survey of public perceptions regarding Urban Air Mobility. The survey covered approximately 1,600 people in (1) Mexico City, (2) Los Angeles, (3) Switzerland, and (4) New Zealand. By region, the percentage of respondents with a positive opinion on the use of air taxis is approximately 70% in (1) Mexico City, approximately 50% in (2) Los Angeles, and approximately 30% in both (3) Switzerland and (4) New Zealand. By age, respondents in the age group of 25 to 34 were the most agreeable to the idea of air taxi use and accounted for approximately 60% of the group. This preliminary survey suggests that people in areas with severe traffic congestion and those belong to the younger age bracket have a high degree of acceptance to using air taxis.

In the cities, transportation systems that include roads and public transport networks are generally already in place. In contrast, the value of air taxis can be demonstrated mainly in areas where demand of users exceeds the transport capacity of the existing transportation system (for example, areas with heavy traffic congestion), and areas where the existing transportation system is not very convenient for users (for example, connections lacking easy access). At the same time, some areas of cities are not adequately served by existing transportation systems. And in these areas, air taxis can differentiate themselves in developing new routes. It should be noted that the air taxi is not an end-to-end mode of transport that directly connects the point of departure with the end destination. To get to an air taxi takeoff and landing area, users will need to secure other ground transportation means. In that respect, the need of seamless connecting of air and land mobility, as Airbus and Audi are attempting to do as mentioned earlier, is an important factor for eVOTL convenience.

Uber is the driving force for air taxi services using eVTOL. The company's 2018 R&D budget for autonomous driving (including for ground vehicles) and eVTOL technologies is said to have reached approximately US$460 million. To develop a service, an ecosystem must be formed with various players while also resolving issues such as security of operations, noise management, and new air traffic control requirements. To that end, Uber is deepening cooperation with developers and manufacturers of aircraft and related equipment real estate developers, and aviation authorities, among others. For aircraft development specifically, the company has established a collaborative network with five partners, including Aurora Flight Sciences, Bell Helicopter Textron, and Embraer (Brazil). In the area of related facilities, it is working together with ChargePoint, which has charging stations for electric vehicles. Uber plans to begin conducting pilot tests in 2020 in Dallas and Los Angeles in the US, and also in Melbourne in Australia. The plan is to start the service in 2023 after obtaining verification of the vehicle’s safety as an aircraft. At the initial stage of the service, the fare for air taxis is expected to be approximately three times that of the existing UberX service (a ground transportation service for private rides, not a ride-sharing service). If the scale of the operation expands with an increase in users, the company expects to be able to lower the rate to the same level as that of UberX. Airbus, too, considers the reasonable air taxi service rates in urban areas to be 2 to 2.5 times that of car travel rates.

CHALLENGES IN DEVELOPING THE eVTOL INDUSTRY

The main issue in eVTOL aircraft development is the battery. The energy density of the most widely used lithium ion batteries is approximately 240 Wh/kg at most. Even this current level of battery performance could power an eVTOL cruising range of several tens of kilometers, such as in the case of the Volocopter. However, for the realization of longer-range air taxis, the commercialization of “all-solid-state batteries” or some other new technologies is needed. Also, lithium-ion batteries use a flammable liquid electrolyte, while the all-solid-state battery uses a flame retardant solid electrolyte, making it more advantageous in terms of safety.
As for the eVTOL service market, the main challenges are: (1) ensuring safety to gain user acceptance, and (2) securing the profitability needed to make the business viable.

For (1), the safety of general aircraft is ensured by standards-based specifications and inspections, trained pilots to handle emergency situations, and a robust ground-based air traffic control system with multi-tiered backup functionality. Current laws and regulations concerning aircraft include those related to the aircraft design and construction, and those related to operations, such as pilots, aircraft maintenance, and operation of ground facilities. Leading aviation authorities, such as the US Federal Aviation Administration (FAA) and European Union Aviation Safety Agency (EASA), have indicated that in addition to applying these existing regulations to eVTOL vehicles, they recognize the need for new eVTOL-specific regulations. The EASA began holding public discussions on eVTOL operations and regulations in 2018. However, the development of new relevant laws and regulations needs time and the aviation authorities may not necessarily respond in accordance with Uber's planned timeline.

As for (2) securing profitability, the important factors are: 1) initial costs, 2) operation costs, and 3) aircraft operation rate. 1) Initial costs mainly include the cost of the aircraft and development costs for takeoff and landing areas. According to an estimate by Uber, the cost of an aircraft is expected to be approximately US$1.2 million per four-seater eVTOL aircraft for annual production of 100 units, approximately US$600,000 for annual production of 500 units, and approximately US$200,000 and for annual production of 5,000 units. The price of the four-seater helicopter "R44" made by Robinson Helicopter, which is a US long-established company, is approximately US$500,000. To ensure eVTOL's competitive edge in terms of price, production volume needs to exceed 500 units a year. The projected sales volume of commercial helicopters in the five years from 2019 to 2023 is approximately 4,000. Meanwhile, the construction cost of eVTOL takeoff and landing areas is estimated at approximately US$120 million for around 80 sites, that is, approximately US$1.5 million per location according to Uber. There are two types of takeoff and landing areas: one that accommodates only departures and arrivals and another type that is additionally equipped with charging infrastructure. For the charging equipment, the borrowing of technologies from other industries (electric vehicles) is expected to contribute to reduce costs. In order to enhance the convenience of the service as a transportation system, a large number of takeoff and landing areas in highly convenient locations need to be built, and to this end, existing heliports and small but underutilized parcels of land will likely play a key role. 2) Operating costs mainly include costs for employing pilots and operating takeoff and landing areas. The cost of a pilot is expected to be approximately US$50,000 per year (estimate for personnel trained to operate small passenger aircraft), and accounts for about 40% of the operation cost (calculation by Uber). As the capacity of an eVTOL is about five passengers at most, a transformation to autopilot navigation will have a major impact on operating costs. However, the realization of a fully unmanned operation using autopilot is said to be more than ten years ahead, meaning that pilot costs need to be taken into account for the time being. The operating cost for the takeoff and landing areas includes the costs for site usage, ground operation personnel, lease of charging equipment, and security services. Reduction of these expenses will also be an important aspect. 3) Aircraft operation rates will be affected by the weather. The impact of thunderstorms, strong gusts, poor visibility, and other weather phenomenon will be greater than on land transportation. Furthermore, operations will be influenced by other factors such as the strong wind generated in the areas surrounded by tall buildings. Therefore, in addition to strengthening the durability of the aircraft to weather elements, the development of technologies for determining the operable time for flights based on local weather forecasts is also needed.

PROSPECTS

A full-scale launch of the eVTOL industry (development and manufacturing of aircraft and related equipment, and service provision) is expected to occur from 2023 to 2025. Market growth factors include Uber's driving force, battery technology advancements and government efforts to improve the value of urban areas by adopting new transportation systems. Among factors that could impede growth, in addition to the difficulties for ensuring safety, there are uncertainties in the external business environment, such as public acceptance and regulations. There are also various calculations of the possible future market size, but one estimate predicts the market for Urban Air Mobility will reach a cumulative value of approximately US$50 billion by 2030. Urban Air Mobility will improve the value of cities and is also expected to be an essential part of the smart cities in the future.

Emergency response services are considered to be the first area that eVTOL's practical use will be realized. It may not be very economically efficient, but the societal need for such services is strong. For example, Germany's ADAC Luftrettung, which operates an emergency rescue helicopter service, is considering replacing its helicopters used for short-distance transportation with eVTOL (manufactured by Volocopter). In the UAE, the Dubai Police Force is considering introducing eVTOL (made by Hoversurf) to ensure emergency transmission capability.

The US, Australia, Germany, Singapore, Austria, New Zealand, the UAE, and other countries are pressing forward with initiatives to realize the practical use of eVTOL as air taxis. At the same time, it is possible that the

introduction of such services could gain traction in local areas of emerging countries and in developing countries where the development of transportation or transport infrastructure is problematic. As air taxis do not require road development or the laying of tracks, unlike cars and railways, the infrastructure will be relatively easy to develop and maintain. In addition, the fact that flight regulations are comparatively less stringent in these areas will also give an impetus to promoting the launch of services. Business deployment in the manner taken by the US venture Zipline, which started a drone-based delivery service for medical-related goods early on in Rwanda, is thought to be possible for air taxi services as well. Furthermore, it is also conceivable that companies with a track record in flight operations in these areas will consequently enter the market, targeting urban areas in both advanced and emerging countries. In such cases, flight achievements may become part of the criteria for obtaining the authorization from the aviation authorities.

In the eVTOL industry, in addition to technologies for all-solid-state batteries and carbon fiber composite materials, the developments of adhesives that meet the need for weight reduction, large scale printing using 3D printers, or other energy-saving technologies are expected. Since technology requirements must be satisfied at a high level in the eVTOL industry, newly developed technologies within the eVTOL industry may later be transferred to other industries, such as the automotive industry.

It will take time for the eVTOL industry to get off the ground, but activities are picking up at the companies involved in this field. As such, trends at those companies should be watched closely.